

Application of Small Unmanned Air Vehicles in Network Centric Warfare

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ABSTRACT

Real-time and detailed information is critical to the success of ground combat forces. Current manned reconnaissance, surveillance, and target acquisition (RSTA) capabilities are not sufficient to cover battlefield intelligence gaps, provide Beyond-Line-of-Sight (BLOS) targeting, and the ambush avoidance information necessary for combat forces operating in hostile situations, complex terrain, and conducting military operations in urban terrain. The US Army has developed a program, known as Networked Sensors for Combat Forces (NSfCF), in order to develop an advanced networked unmanned/unattended sensor system which can surveil gaps and provide the Commander with real-time, pertinent information. Through the use of networked unmanned sensors to provide remote monitoring of gaps, NSfCF will increase a unit's area of coverage, and will provide the commander organic assets to complete his Battlefield Situational Awareness (BSA) picture for direct and indirect fire weapons, early warning, and threat avoidance. The NSfCF program as a whole is developing sensor packages for unmanned ground vehicles, Small Unmanned Aerial Vehicles (SUAV), and unattended ground sensors using advanced sensor technologies. This paper will focus on the role of the SUAV as an asset which is controlled from an integrated Reconnaissance Surveillance and Target Acquisition hub vehicle serving as an extended range sensor to provide beyond line of sight video data for timely threat detection, recognition, identification, and targeting. The ability of the SUAV to quickly react to mission changes such as evaluating alarms from an array of networked unattended ground sensors will also be reviewed. Discussion will also include how NSfCF is developing and evaluating sensor technologies for man portable Small Unmanned Aerial Vehicles (SUAVs) and demonstrating how SUAVs are able to provide ground commanders with live video from a re-taskable airborne sensor platform for reconnaissance, surveillance, targeting and local security. This paper also describes the types of aircraft used, the various sensor payloads and sensor limitations, SUAV specific image processing and the mission flexibility derived from being part of a network centric hub. Evaluations/conclusions from field trials will be included with lessons learned and how these lessons are leading to derived requirements for aircraft state data, sensors, data links, data formats, payload capacity, functionality, ground station processing and reliability.

Keywords: Networks, Sensors, UAV, ISR, RSTA

1.0 INTRODUCTION

1.1 Need for Timely Data

Situational awareness which is timely and factual is critical to the survivability of a medium weight force that cannot depend on extensive armor for survivability. Current RSTA (reconnaissance, surveillance,

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target acquisition) capabilities are not sufficient to provide coverage of the intelligence gaps, beyond-line-of-sight targeting, and ambush avoidance necessary for the Combat Force operating in the “red zone,” complex terrain, and urban areas. The Networked Sensors for the Combat Forces program has demonstrated a new generation of networked, low cost, distributed unmanned sensor systems organic to the RSTA team for the Combat Force. The goal is to extend the eyes and ears of the RSTA element to provide the warfighter situational understanding and targeting information for enhanced survivability (early warning and threat avoidance) and lethality (direct and indirect fire weapons) through networked unmanned sensor systems.

1.2 Concept

The NSfCF project has been developing, integrating, and demonstrating sensor suites and operational concepts for small-unmanned aerial vehicles (SUAVs) as part of an overall single reconnaissance system. The sensors under development for the SUAV platforms are uncooled infrared monochrome and color day TVs. These sensors are used to feed a network which is robust (secure, jam resistant, stealthy) low power communications system that is self-forming, self-healing, and that has anti-jam capability, low probabilities of detection and interception, unique waveforms, and is capable of rapidly interfacing with the tactical internet and tactical C2 systems. The NSfCF project developed for the SUAV a command and control (C2) set of software tools specific that include mission planning, sensor monitoring, dynamic re-planning, and sensor management functions. The SUAV data was fused as part of a smart sensor management system which enable the information collected by the SUAV to be rapidly processed, communicated, and presented to a human decision maker in real-time; thereby replicating human “eyes on target” without exposing the human to the hazards of a given situation and/or limiting coverage by his location.

The SUAV capability as part of NSfCF provided the battlefield commander organic highly mobile sensor enhancing his real-time Battlefield Situational Understanding (BSU); supported sensor-to-shooter links for targeting Line of Sight, Beyond-Line of Sight, and Non-Line of Sight fires; provided sensor-to-decider and maneuver information, and to provided inputs to sensor-to-analysis actions to expand the Common Operational Picture’s details of the operational environment. The networked SUAV provided remote monitoring of areas of interest in excess of 9Km not covered by higher echelon surveillance assets and without placing soldiers in harm’s way, increased unit areas of coverage (force multiplier), and will provided near real time BSU and targeting data for early warning to speed decision making and reaction time.

This paper will describe all of the SUAV sensor and system components and provide qualitative results of the most recent demonstrations. Technical performance data is still under analysis but the baseline capability of a networked SUAV as part of a system of systems approach to provide a commander actionable information was successfully demonstrated.

2.0 SUAV SENSORS AND SYSTEMS

2.1 Sensors for Small UAVs

Small UAV Sensor (SUAV). The SUAV Sensor Package was designed to provide autonomous, day/night, all weather, tactical imagery and acoustic data collection of non line of sight areas. In the future, the SUAV sensor package may be applied to fixed wing and/or VTOL (Vertical Take Off/Landing). The sensor suites comprised of on-board electro-optic IR imagers, color TV, and acoustic sensors, mounted in prototype SUAVs capable of autonomous flight and search capabilities. The SUAV sensor



package was also designed to transmit full resolution imagery to the ground station; provide large area mapping services through image mosaics, and support dynamic re-tasking of targets while in flight.

Air Vehicles

An SUAV being used for the project is the BUSTER man-portable SUAV manufactured by Mission Technologies, Inc., figure I. The BUSTER is designed to be a quiet, high endurance SUAV capable of automatic takeoff and landing with waypoints changeable in flight. The aircraft weighs 10 pounds and is designed to carry up to 2 pounds of mission payload. The BUSTER air vehicle, constructed of Kevlar, measures three feet in length with a four-foot wingspan. It is designed to be capable of over 2 hours of continuous operation at a



Figure I



Figure II

cruise speed of approximately 35 knots. Each

BUSTER air vehicle is equipped with an onboard GPS-guided autopilot which is designed to be commanded and mission planned from a laptop computer interface at the ground control station. Sensor payload volume is approximately 60 cubic inches measuring 3" x 5" x 5". Standard camera configurations include both downward, (15° forward of nadir), and side-looking options. Sensor video and data telemetry is designed to be relayed to and from the ground control station via analog data links.

A second small UAV, being used in the NSfCF program, is the Aeroenvironment Raven, figure III. It is slightly smaller than the Buster and uses a battery powered electric motor for propulsion. While it is technically less complex than the Buster, it has proven to be very reliable and is capable of carrying either a 320 x 240 IR sensor or a color CCD camera. The sensors are housed in a detachable nosecone as shown in the graphic, figure II, and the aircraft has been configured to use the Portable Image Chip Generator (PICG) software to capture still images of targets from the video stream. The Raven is man-portable, hand-launched, and capable of fully autonomous (GPS)



Figure III



Figure IV

or manual flight operations with an endurance of 90 minutes. It has a wingspan of 55 inches, is 36 inches in length, and weighs 4.2 pounds, including the payload. The Kevlar composite aircraft is designed to operate at altitudes of 150 to 1,000 ft AGL, in excess of 9Km (LOS) range, and cruises at 30 mph. The aircraft and ground station fit into two packs that weigh a total of 32 lbs.

A third small UAV, being used in the NSfCF program, is the Aeroenvironment Pointer, figure V. It is slightly larger than the Buster. Like Raven, Pointer uses a battery powered electric motor for propulsion. The aircraft is also man-portable, hand-launched,



Figure V

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and capable of fully autonomous (GPS) or manual flight operations with an endurance of 90 minutes. It has a wingspan of 9 feet, is 6 feet in length, and weighs 10 pounds, including the payload. The Kevlar composite aircraft is designed to operate at altitudes of 150 to 1,000 ft AGL, greater than 9km (LOS) range, and cruises at 22 Knots. The Pointer has proven to be reliability and nose payload bay is capable of carrying a 2 pound payload capacity for sensors. The sensors are housed in a payload bay as shown in the graphic, figure IV. The purpose for using Pointer was to evaluate 640x480 element IR sensors still in development which needed greater payload bay volume. The pointer has also been configured to use the Portable Image Chip Generator (PICG). The aircraft and ground station consists of 3 packs and is 2 man portable.

Sensors

Gantz CMH112 Color TV Camera. The Gantz CMH112, figure VI, is an NTSC output, one quarter inch, inline transfer Color CCD. The camera has 768x492 pixels and used as an interlaced system with 470 TV Lines resolution. It has an auto electronic shutter capable of a range of 1/60 of a second to 1/20,000 of a second. The weight is approximately 10 grams as tested. Input power is 12 volt DC and uses less than 1.2 watts. Multiple sensors with multiple Fields Of View (FOV) were used including 54°, 34°, 25°, and 17° all having an F2.0 optics.



Figure VI

Raytheon SB-246 "NAP" Configuration Camera. The Raytheon SB-246 Nap configuration camera, figure VII, is a 640x480, 25µm pixel pitch VoX uncooled infrared camera. Consisting of an octagonal shaped package, the camera measures 2.75" wide x 3.75" high x 2.5" deep and weighs approximately 0.6 lbs. The SB-246 utilizes uncooled VoX technology with a small pixel large format array packaged in a thermal electrically stabilized detector assembly. Factory calibrated, the SB-246 features an external shutter paddle that is motor driven internally by the camera which is designed to provide capability for one-point correction at periodic points during camera operation. The SB-246 features an F/1.4, 22mm lens that provides a 40° horizontal x 30° vertical field-of-view.

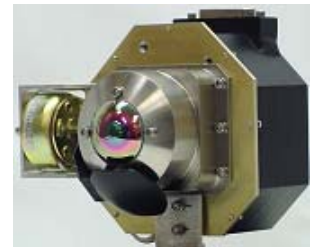


Figure VII

DRS Nytech U6000 Uncooled IR Camera. The DRS Nytech U6000, is a 640x480, 25µm pixel pitch VoX uncooled infrared camera, figure VIII. Consisting of a cylindrical shaped package the camera measures 4.33" in diameter x 2.56" in length and weighs approximately 0.8 lbs. The U6000 utilizes uncooled VoX technology with a small pixel large format array packaged in a thermal electrically stabilized detector assembly. Factory calibrated, the U6000 features an internal (directly behind lens) shutter paddle that is motor driven internally by the camera which is designed to provide capability for one-point correction at periodic points during camera operation. The U6000 features an F/1.0, 22mm lens that provides a 40° horizontal x 30° vertical field-of-view.



Figure VIII

Restrahlen Effect Camera. A dual color countermines sensor, figure IX, for Small UAVs is currently under testing on a surrogate manned aircraft. Designed for a VTOL application, it provides a low cost approach to realize a significant improvement in search and detection of buried mines in roadways. The passive long wave IR system scans the road below the UAV at an altitude of 100ft, looking for thermal signatures that may have been generated by soil disturbances due to mine emplacements. Any areas that show disturbances will be classified as possible targets for further investigation. The system will augment conventional ground based mine detection systems and can increase route search rates. Detection algorithms will run in near real time on a ground station in a vehicle following the SUAV. The algorithms will extract candidate targets and transfer coordinates of the targets and possible local target images to the ground vehicle for further interrogation and declaration of targets in the suspect areas. This mine detection system leverages the latest in uncooled longwave IR imager technology. The LWIR bands from this system are processed to take advantage of a spectral anomaly associated with disturbed soil. A NIR imager is boresighted in the mine detection system to improve clutter rejection of the detection algorithm. This is accomplished by enabling discrimination between vegetation and the normal road surface. The algorithms in the ground station process all of the spectral bands together in order to identify areas of interest. While this technology is being developed by the NSfCF project, it will not be advanced to the point of flying on a SUAV during the life of the project. Manned aircraft will be used for project testing.

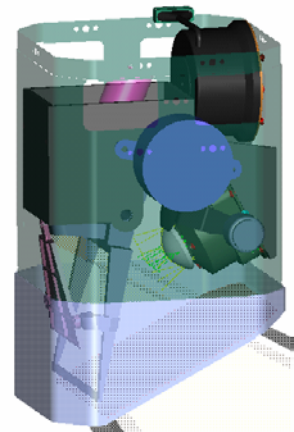


Figure IX

Software

A new development for SUAV use in a networked sensors environment, the Portable Image Chip Generator (PICG) software is a Government owned targeting software package. The PICG software is used to capture still frame target images from the streaming video at the operator control station. The operator uses a touchscreen display to view the SUAV live imagery. When a target is detected, the operator touches that area of the display and a target image chip is created. This chip not only contains the image but also the targets location, date and time stamps. Initially envisioned as an end product of the NSfCF project, the software development was accelerated for demonstration in FY02/03. Developed for a Microsoft Windows environment, the PICG targeting software is designed to be operated on any Microsoft Windows machine. The PICG targeting software is designed to be capable of outputting image chips with targeting data imbedded in several formats including Bitmap, and NITF 2.1. In addition the PICG software, as setup with the BUSTER or Raven air vehicle, is designed to produce aircraft update messages - "heartbeats" - for tracking by higher-level electronic systems.

2.2 Command & Control for the SUAV

A sensor management center was developed as part of the overall NSfCF project with an intelligence reach-back capability. The management center includes software management tools to provide smart data management and to enable cross cueing between sensor platforms. C2 tools are leveraged from existing programs and further enhanced to enable the RSTA commander to perform mission planning, execution, and information collection from the SUAV in a timely manner. The SUAV as part of the C2 system provides the commander with an enhanced common operating picture (COP) and better prediction of enemy actions by continuously tracking enemy movement based on the real-time information collected. In addition, the C2 workstation and software management tools will allow for UAV sensor planning and deployment.

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This software module is designed to support the tasks to be performed by the Reconnaissance and Surveillance Vehicle (RSV) commander and is built as a new software module to an existing C2 software package called MC2. The sensor planning and execution module is designed to provide the commander with a suite of C2 tools to assist in the generation of the SUAV sensor plans to support the commander's requirements for intelligence collection, intelligence, surveillance and reconnaissance (ISR) coverage, situational awareness, targeting information, sensor-to-decision-maker links, and Battle Damage Assessment (BDA). It is also designed to assist the commander in conducting resource allocation, best-placement of the SUAV as well as other sensors, execution-monitoring, dynamic re-planning, and smart management of organic unmanned platforms and sensors under control of an RSV. The C2 sensor planning and execution tools are designed to assist the commander in the generation of flight paths and search areas for UAVs. The module is designed to take into consideration the impacts of weather and terrain on platform and sensor performance during all phases of the mission. While monitoring the execution of the sensor plan, MC2 is designed to provide the commander with the "Common Operating Picture" of near real time reconnaissance information, thus enhancing situational awareness.

2.3 Sensor Fusion

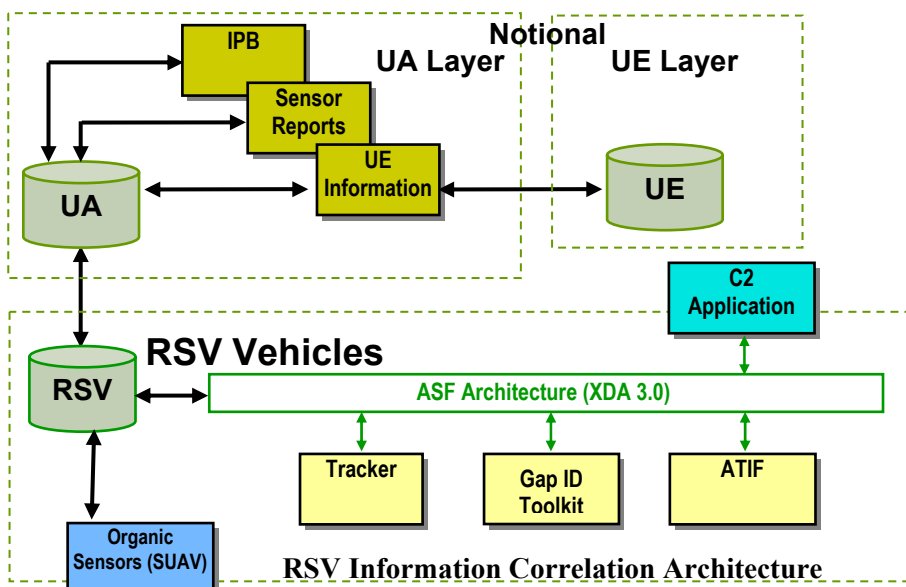


Figure X

The Sensor Exploitation And Management System (SEAMS), figure X, is designed to provide a means of compiling raw sensor data into information that is useful to the user. It consists of four components – a Fusion module, Tracker module, GAP ID module, and a SEAMS Interactive Display (SID). The Fusion module is designed to perform level 0/1 fusion of target reports - as defined by the Joint Directors of Laboratory (JDL) model - in order to reduce the number of false alarms and

redundant target reports. The Tracker module is designed to analyze the motion of target reports, taking into account local terrain features, and develop a path along which a target is likely to travel. The GAP ID module is designed to identify areas where higher echelon reconnaissance assets cannot provide coverage, thus defining areas requiring coverage by the RSV's organic assets. The SID is designed to provide a graphic representation of the operating area as well as target reports and tracks output by the Fusion and Tracker modules, thus providing the COP for the RSV's area of responsibility.

3.0 COMMUNICATION & INTEGRATION

The communications products in the NSfCF project are characterized as ad-hoc, multi-tier networking, self-forming, and self-healing. The two tiers of the network architecture include sensor communications and gateway communications. Each is discussed below. The sensors, systems, and communications are all integrated via the Sensor Information management Layer (SIML) into the Reconnaissance and Surveillance Vehicle (RSV).

3.1 SUAV Sensor Communications

The basic SUAV communication link is a 1.72Ghz RS-170 Video transmitter with a 2 way UHF data link for aircraft control. The link is a line of sight system with omni-directional antennas providing video and communications to ranges of up to 10Km . This link was used for simplicity and was in the available radio band allotted to the NSfCF system for experimentation in the user lead, lab supported demonstrations.

3.2 System-of-Systems Integration

In order to have an integrated SUAV which can provide timely situational awareness, the SUAV products must be disseminated in an efficient clear manner. In order to achieve this, NSfCF developed a methodology which can provide for timely reporting of RSTA data supplied by the SUAV as well as other organic sensors associated with the RSV.

Sensor Information Management Layer. NSfCF has a Sensor Information Management Layer (SIML) is designed to be a bi-directional message exchange and management process. This allows sensor systems like the SUAV to provide targeting, status and health information asynchronously and efficiently, and to transform this data into standardized formats (both information and imagery). The SIML is designed to distribute this information to requesting processes both onboard and remote to the RSV platform. Additionally, authorized processes will be enabled to send control messages through the SIML to sensors and/or platforms including the SUAV to control their mission functions and operational modes.

Architecture. The SIML, figure XI, and NSfCF project architecture is based on the current thinking portrayed by the Combat Forces future development community. It defines 3 major components: Standardized sensor interface protocol, a sensor data management layer, and a Service Oriented Architecture for distribution of data and information into a systems of systems common operating environment. This model establishes a process by which unique sensor information is transmitted using a standard message format to a sensor management layer where data conversion and process control is implemented. The output of the sensor data management layer is pushed into a publish/subscribe Service Oriented Architecture (SOA) which allows the axis to the SUAV and its near-real-time data products. The information placed into the SOA can be distributed as needed by requesting processes and/or the SUAV system in real-time.

Design. The NSfCF project SIML design defines 3 components: Portable Sensor Data (PSD) message format, Sensor Data Interface (SDI), and Subscriber Information Interface (SII). These 3 components

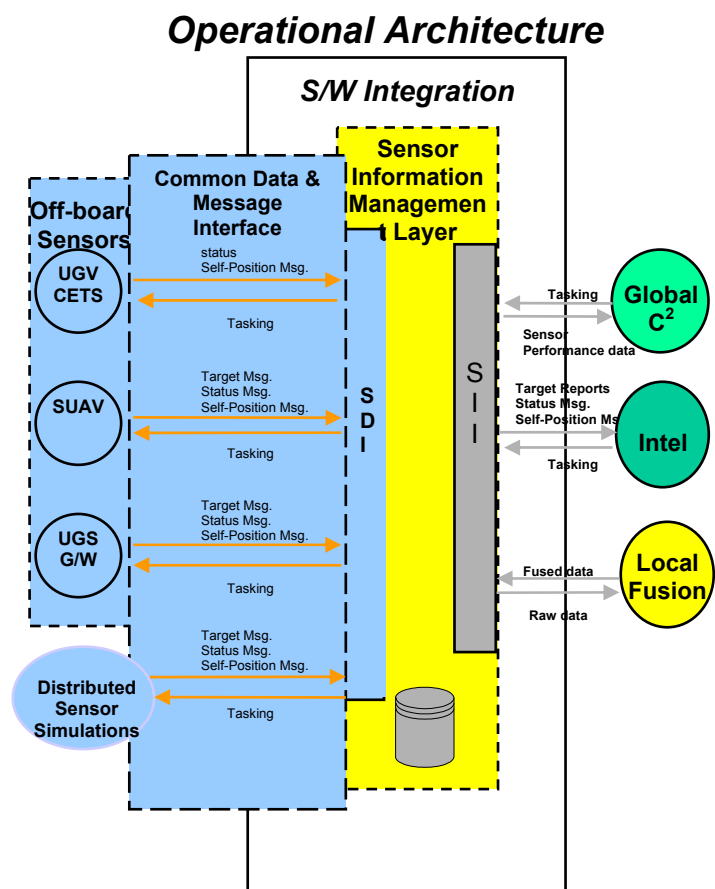


Figure XI

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combine to establish a sensor management and information distribution “middle-ware” that can accept input from the organic sensors network layer which includes the SUAV system via the SDI. It can then distribute SUAV sensor information to requesting processes/systems via the SII using a Common Object Request Broker Architecture (CORBA) SOA mechanism. The SIML SII process is resident within the Sensor Exploitation And Management System (SEAMS) Server application and is functionally an extension of the services and functions (data distribution and archival) inherently provided by the SEAMS server. The SDI Master application is a remote process that connects via an IP transport layer to the SEAMS server application and via multiple transport mechanisms (IP transport layer, serial port, etc.) to the organic sensor network layer and hence to the SUAV.

Vehicle Integration. The NSfCF program has developed a surrogate Reconnaissance and Surveillance Vehicle (RSV) platform to serve as a sensor command & control, and data management center, figure XII. The RSV platform contains workstations for command & control, sensor operation, and data fusion. The RSV vehicle platform being used for the NSfCF project integration testing is a converted HMMWV ambulance. The HMMWV cutaway rendition of the RSV layout is shown here along with a vehicle photograph, figure XIII.



Figure XII

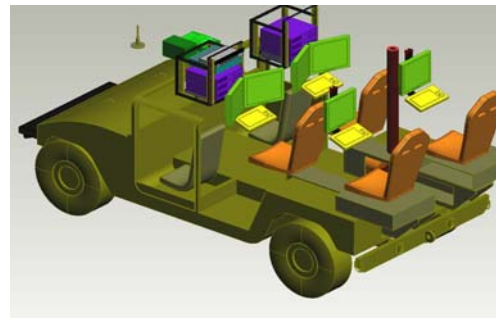


Figure XIII

The RSV consists of four operator workstations, one each for an MC2 operator, SUAV operator, SEAMS operator, and system administrator, figure XIV. The forward left hand display is the SUAV operators work station. Imagery is viewed from this location and target reports are first generated via a touchscreen display. The reports are then reviewed by the RSV commander and sent forward onto the tactical network for dissemination.

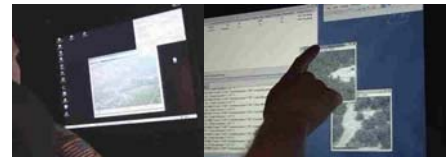


Figure XIV



Figure XV

To the right of the SUAV operator is the MC2 work station where the SUAV reports are collected and placed on the tactical net along with reports from the other RSV sensors, figure XV. This too is a touch screen display allowing the user to easily select and package information for the tactical net.

This configuration is designed to meet the minimum exit criteria that system-of-systems integration reduce manpower requirements to 4 operators per sensor hub. The goal requirement is for two operators and the program desires to meet that goal through maturation of the system and elimination of SEAMS and network administrator oversight through improved automation.

4.0 TESTING

4.1 Concept

The goal of the NSfCF project for the SUAV was to develop optimized sensor packages. Additional goals for the SUAV included the development of Command and Control (C2) software tools to include mission planning, monitoring, dynamic re-planning, sensor planning and management functions; and to demonstrate a system-of-systems capability when fusing information from the SUAV with various other unmanned sensor systems. Vigorous, robust, and realistic testing is underway to validate the SUAV requirements and satisfy the technical and operational exit criteria. In addition to laboratory integration testing and field data collection, the NSfCF project underwent 2 major field test events, or demonstrations, wherein the sensors and systems were used in operational scenarios.

4.2 Demonstration I

The first demonstration was “Lab Led, User Supported” in that it will focus on technical integration aspects to identify technical shortcomings prior to the final demonstration and exit criteria testing. This demonstration was conducted in July 2004 on a US Army test range and used live troops to operate the RSV, and technical personnel deployed the SUAV sensor systems. Since this demonstration occurred during the development cycle, some surrogate SUAV systems and sensors were used in place of some items that are not yet field ready. These included the Raven and Buster SUAV and prototype 640 x 480 LWIR bolometer cameras. The overall objective of the SUAV testing was to demonstrate connectivity between the SUAV sensor, other various sensors and the sensor management tools in the RSV prior to sensor performance testing. Basic SUAV sensor performance was assessed, although sensor performance definition is not an objective of this testing.

The desired culmination of integration testing was the execution of a limited vignette in which all sensors were simultaneously connected to the RSV to provide data which is fused within the RSV to form a common operating picture (COP) of the area of operation. The vignette was based on a subset of mission tasks extracted from future experiment plans. Friendly forces included a notional manned main unit and the RSV and its unmanned systems. The main unit was located at Objective Villborn with the RSV located at an eastern, secondary avenue of approach, Objective Liberty as shown on the diagram. Opposing forces (OPFOR) were composed of a number of tracked and wheeled vehicle targets and intelligence data indicated that the OPFOR was approaching the objectives from the North. The vignette included generation of a sensor deployment plan within the RSV. Details of the plan included an NAI at the intersection of two major trails that was designated as the place to employ the UGS field. The SUAV was given the tasks of clearing the open area along the Avenue of Approach and then confirming vehicle locations reported by higher echelon intelligence reports. The SUAV was also used to help recognize vehicles that came through the NAI and to monitor the route they followed and their actions. The SUAV was also used following a simulated attack of two enemy track vehicles to determine BDA. The vignette was successfully demonstrated thereby validating the baseline capability.

4.3 Demonstration II

The second demonstration will be “User Led, Lab Supported” in that it will focus on tactical and operational aspects of the project. The primary objective of this demonstration is to answer the “so what?” questions of the user, and to illustrate the value of networked sensors to the combat forces. This demonstration will be conducted at a US Army field training site. This demonstration will be immediately preceded by technical testing in a field environment wherein the SUAV sensors and aircraft systems will be instrumented and exercised to determine satisfaction of the technical exit criteria by the final versions of the selected sensors and systems.

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4.4 Demonstration I Testing Conclusions

The baseline capability of a networked system of systems approach to provide a commander actionable information was successfully demonstrated as part of Demonstration I. The conclusion of initial SUAV testing as part of a networked of distributed unmanned sensors that the SUAV allowed the commander to significantly increase his area of coverage and provide actionable information. Overall, the SUAVs used and their sensors performed well. The SUAV flew in all types of weather to including cold, hot, winds to 25 knots, light rain and snow. Mission durations were typically 45- 60 minutes each with 6 hrs of flight per 24 hour day. The SUAV operators were able to use the aircraft to get and maintain good situational awareness of the avenue of approach that was not being observed by a manned system. The SUAV was able to confirm a reported enemy location, monitor activity in the avenue and conduct BDA of simulated strikes.

The primary task of the SUAV was to search in and around the local medium density forest and roads for targets. The greater part of SUAV operations were during daylight hours so the day camera was used the majority of the time. The day color camera when flown allowed the scout to easily detect and in many cases ID targets along its flight route. It allowed the scout to pick up the visual cues that were agreed upon as representing BDA cues following the simulated strike (vehicle orientation, dropped ramp, crew alongside, etc.).

Sensor Function:

Three basic types of sensors were flown in a fixed (non gimbaled) configuration: a color 640 x 480 pixel CCD, a 320 x 240 pixel bolometer Long Wave Infrared (LWIR), and an limited set of flights with the 640 x 480 bolometer LWIR. The RS-170 output of each of the sensors was used. Payload space and weight limitations prevented the use of gimbals. It was found that the Field of View (FOV) relative to sensor resolution and down look angle became quite important relative to which task was being performed. Large FOVs with poor resolution were as non productive as very narrow FOVs with very good resolution. Looking at or near the horizon, rarely provided enough resolution to do the recognition task at the operational altitudes of 200 to 300 feet due to large path lengths. Target detection became difficult when altitudes of 600-700 feet were needed to preserve Line Of Sight communications for the data link more than doubling path lengths. The sensor FOV, aircraft altitude, and the GSD resolution were largely driven by the aircraft used and its dynamics. A more stable platform may be able to fly higher with narrower FOV sensors as long as the foot print and resolution stay the same.

Generally for the aircraft used, a forward FOV of at least 25 degrees and down look angle of 30 degrees was needed to search for targets for the cameras tested. The 25 degrees was deemed the "Sweet Spot" of acceptability for day 640 x 480 CCD and LWIR bolometer 320 x 240 and 640 x 480 cameras based on the loss of resolution on the ground vs. range. The combination of sensor resolution, look down and FOV was a compromise between the ground sampling distance (GSD) to do the target detection/recognition task, the speed at which the imagery passed through the camera, and the FOV needed to orient the SUAV operator and ensure usable imagery under gusty and turbulent environments. This provided the SUAV controller a time on target of about 10 seconds. When looking more nadir, as in the Buster installation, potential targets passed too quickly through the scene even though image quality was good. Image flow was too great to insure target detection and the relatively small ground foot print created disorientation to the operator. If a potential target was detected, the inability to relate the detection to the surrounding scene greatly reduced the operators' ability to revisit the same location for further analysis or provide sufficient situational awareness. A steep look down angle did improve target recognition but time on target was often minimal. A potential solution to the current paradox of resolution, FOV, and situational awareness is of course a mini pan and tilt capability which can look forward to detect and then pan down to recognize. NVESD is currently developing a small less than 1 lb gimbal which can provide some roll, pitch and yaw compensation and will be tested as part of Demonstration II.

Search Techniques:

Two basic techniques were employed to provide area coverage during general target searches. The first was to basically command point to point flying of the SUAV to follow roads and forest tree lines. Here the operator could either manually direct the aircraft via the live image display in the direction desired or set waypoints via the SEAMS sensor management layer which could dynamically change the aircraft flight path real-time as needed. The Second technique was to fly back and forth in a push broom manner over the assigned area. To aid in searching large areas, Night Vision and Electronic Sensor Directorate (NVESD) has developed software that generates search patterns of a selected area. These algorithms take into account air vehicle altitude, speed, sensor FOV and wind direction and speed. Both techniques had their advantages and disadvantages. Flying the roads and tree lines enabled the obvious attacks to be picked up early. However, more covert operations which may spread though the wooded area were missed. The opposite is true for the push broom. Few areas provided sanctuary to the OPFOR but the time to search was much greater.

Often a mission task of the SUAV would be to evaluate a target detection provide by an unattended ground sensor. In this case, either the automated mission planner of the SEAMS or a manual input to the aircraft rout planner would direct the aircraft to the UGS location. Either a race track or figure eight over the target area was then flown to evaluate the situation. This provided a quick and easy way to confirm an UGS alarm.

The ability to search an area with as little manual intervention/redirection of the aircraft was deemed very important to the SUAV operator. In addition, the success of the SUAV in being able to quickly respond to the local commanders needs for updates and situational awareness has shown the necessity to have multiple SUAVs in operation at the same time to provide constant coverage over a large extent of the battle front. Improvements in the SEAMS process within the RSV will allow up to 3 SUAVs to be flying simultaneously in DEMO II to evaluate the impact of such coverage.

Data Link:

The data link was a standard 1.72 GHz data link for imagery and a UHF link for aircraft/sensor control. The bandwidth of the data link limited the performance of the 640 x 480 Color and 640 x 480 bolometer cameras. The UHF link had problems maintaining link due to low altitude and line of sight obstructions at the extended ranges of 8 to 9 kilometers. This caused the aircraft to use its default reacquire mode of circling up in altitude to re-establish the link at higher altitudes. At extended ranges, the SUAV often needed to operate at altitudes of 600-700 feet. The L-Band video link rarely lost link before the UHF. In DEMO II a ground tracking antenna will be used to aide in maximizing link performance. A digital mode for the video link which could pass full quality images but at a reduced rate or provide single snapshots in full resolution to the ground as chips is currently under consideration for DEMO II. This will improve the quality of the image provided to the mission commander in the RSV for dissemination to the tactical net.

SUAV Image Products:

The primary product of the SUAV/SUAV work station were target location and image chips provided by the Portable Image Chip Generator (PICG) which collected the imagery in and around the target pointed out on the touch screen of the SUAV operator station. These chips were 160 x 160 pixels in size, time and dated, and contained calculated location coordinates at each of the 4 corners of the image. Once an area was "chipped out", the operator would touch the target and the coordinates to that target were calculated by the triangulation of the 4 corners to that pixel location. The performance of the target location error varied from sub 80 meters to as poor as 1000 metres off. Typical Target Location Errors (TLE) were on the order of 200 meters. This was attributed to the lack of attitude knowledge (roll, pitch and yaw) of the aircraft particularly under gusty conditions. In addition, the inconsistent alignment of system offsets and the latency of GPS data as well as other heading and altitude data contributed to poorer

Application of Small Unmanned Air Vehicles in Network Centric Warfare

TLE. The aircraft processor which provided aircraft data packets were not precisely time stamped and were off by as much as a second. Improvements in data time stamps and offset error alignments are being implemented in the aircraft and in the PICG software to reduce errors and improve TLE for DEMO II. It is anticipated the improvements will provide TLEs of less than 100 meters on average in even gusty conditions.

Future Image Products:

NVESD is currently developing a small HDTV system for SUAV use. When integrating high-resolution sensors into a SUAV one limiting point in the overall systems is the SUAV radio package. In order to keep system weight and power requirements low, SUAV radios tend to be limited in bandwidth. To address this situation NVESD is working on an HDTV and encoder board package. This combination will provide two modes of operation. Mode one will reduce the resolution of each frame allowing low-resolution full frame rate video to be sent to the ground. This mode will allow the SUAV operator to navigate to a desired location with a smooth video display. Mode two will provide the SUAV operator with a reduced frame rate of full HDTV resolution. Mode two would be used once the target location has been reached. These frames will provide a level of detail that is not currently available from a SUAV platform. When combined with the Portable Image Chip Generator, this package will allow the SUAV platform to generate HDTV resolution target images that are geo-located. The Portable Image Chip Generator already has the capability to send target images to any location on the battlefield network.

SUAV Limitations:

During our testing we found the overall strengths of the SUAV platform to be greater than its limitations. However there are several limitations that were observed. Because of the small size and power combinations found in the electric SUAV's, weather is of particular concern. Each system has its own limitation to make significant head way during windy conditions. On the other hand gas powered SUAV's handle windy conditions better than the electric units, but at a cost of additional complexity in operation. Current SUAV gas engines require some on site tuning depending on weather conditions. Additional work is needed to replace the gas powered units with low maintenance heavy fuel powered systems.

5.0 CLOSING

The baseline capability of a networked system of systems approach which included an SUAV which provided a commander timely actionable information was successfully demonstrated as part of Demonstration I. Initial testing indicated that the SUAV enabled the commander to significantly increase his area of coverage under dynamic situations and provide actionable information. Sensor reports and imagery was received and displayed within the RSV platform to the operator. The SUAV provided a critical capability to the NSfCF RSV system of systems by its ability to assess the how big the threat was, to quickly be re-tasked and repositioned, and overall mobility. Its worth was proven by the high demand placed on the SUAV by the requests from the field commander to the RSV commander for immediate updates of critical battle activity.

The result is a viable system of systems capability that improves battlefield situational understanding (BSU). Targeting and BSU information so developed will be available to RECCE units, warfighters, and staff planners through appropriate links via the networked Battle Command System.

6.0 REFERENCES

- [1] Klager, G., US Army Night Vision and Electronic Sensors Directorate, *Networked Sensors for the Combat Forces*. SPIE – The International Society for Optical Engineering, Oct 25-27, 2004.



Application of Small Unmanned Air Vehicles in Network Centric Warfare

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2 May 2005

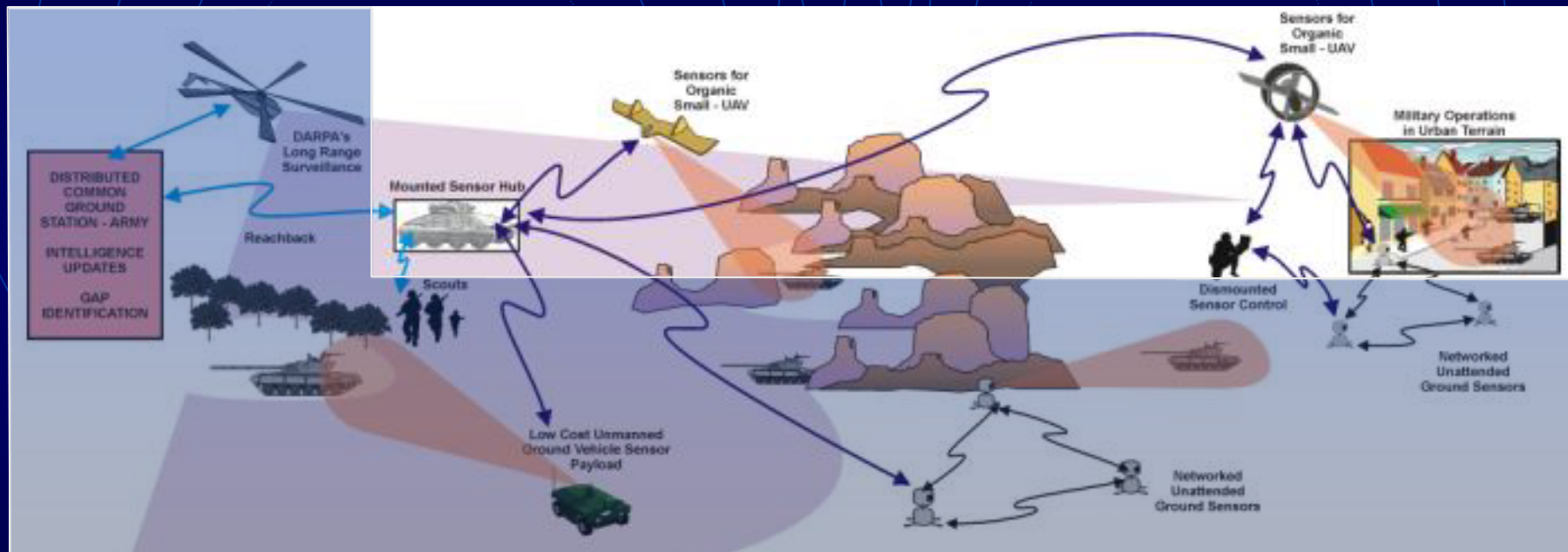
Network Sensors for the Combat Forces (NSfCF)

Command and Control Concept



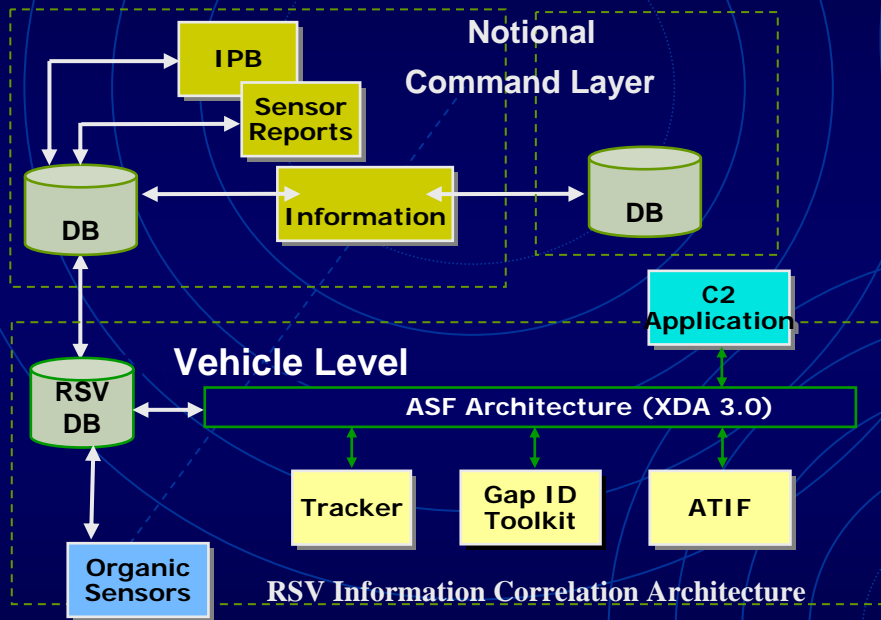
Networked Sensors for the Combat Forces

Objective: Develop a new generation of low cost, distributed, unmanned sensor systems: consisting of networked UGS, UGVs and small-UAVs organic to RSTA team



**DISTRIBUTED SENSORS FILL THE BATTLEFIELD SITUATIONAL AWARENESS GAP
- COMPLEMENT GLOBAL SURVEILLANCE -**

Information Correlation & Target De-Confliction



Focus: Correlation of sensor information to provide target de-confliction.

Approach:

- Trackers and fusion components are inserted as components or modules into a common government owned architecture/framework.

Advantages:

- Ability to process real-time data without any latency or staleness of information.
- Ability to change or modify components without rebuilding from bottom up.
- The ability to publish and subscribe data allows access to all data types including raw information.
- Open architecture approach.

Key Areas Addressed:

Correlation:

- Pre-processing sensor information.
- Correlation of sensor information so as to provide target de-confliction of higher echelon and lower echelon sensor information.
- Provide Gap ID tools

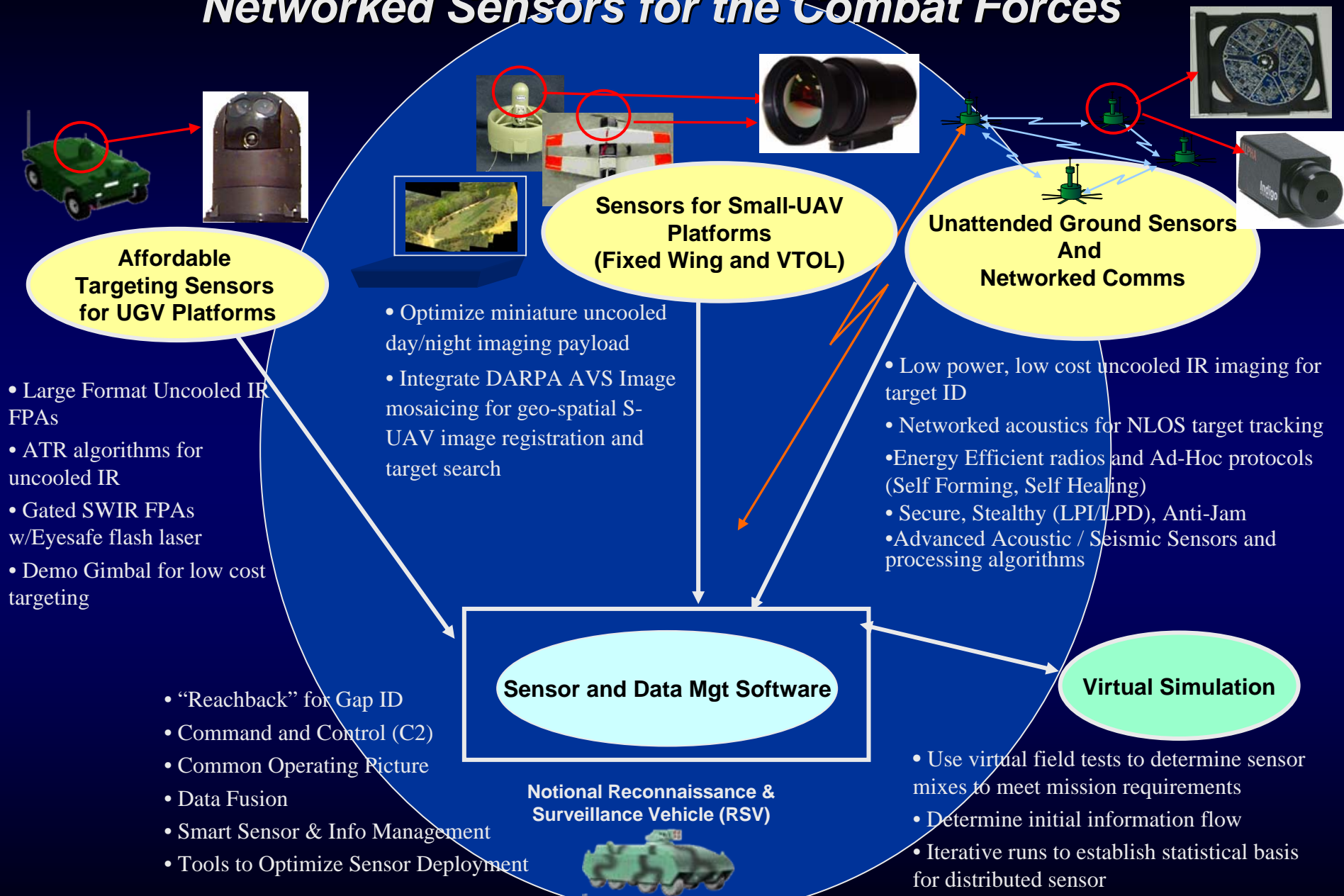
Interface to C2 System:

- Reduce the amount of information that has to be passed to a commander.
- Provide time-critical target information when necessary.

Trackers and Fusion:

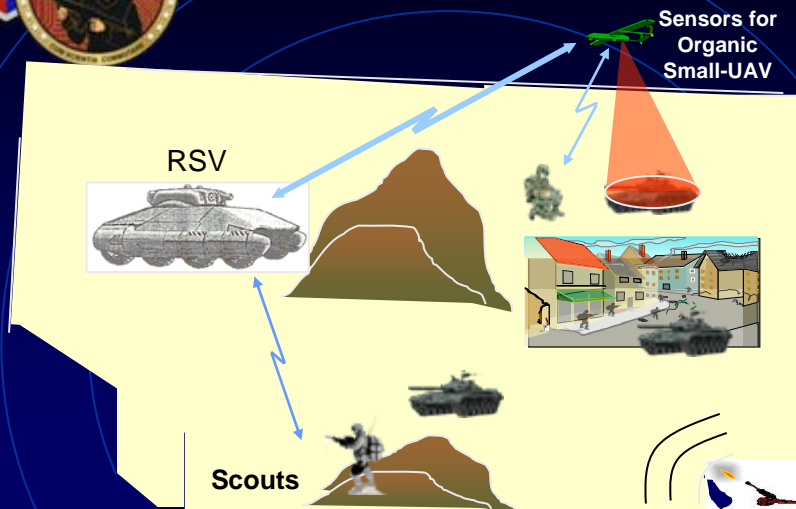
- Technology enables real-time tracking and fusion of multiple INT's.
- De-conflict reports from multiple sensor assets using trackers.

Networked Sensors for the Combat Forces

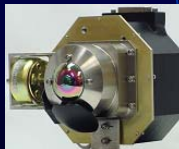


Distributed Sensors Fill the Battlefield Situational Awareness Gaps – Complement Global Surveillance

Program Approach for Small UAV Sensors



Low cost compact, lightweight sensors to provide rapid airborne reconnaissance, surveillance, target acquisition capabilities organic to the small unit



Focus: Demonstrate the ability of next-generation SUAV sensor systems to fill gaps in situational awareness and perform targeting. within a system-of-systems architecture.

Approach: Integrate low-cost sensors on available small aerial platforms and export data into system-of-systems architecture.

Advantages:

- Provides low cost, real time, organic, small, autonomous sensor capability for RSTA missions.
- Extends the utility of Small UAV systems through an integrated and networked implementation.
- Demonstrates real-time simultaneous operation of multiple Small UAVs and sensors.

Key Areas Addressed:

Sensors:

- Integrated low-cost mid performance narrow field of view 320x240 Uncooled Infrared Sensor
- Integrated high performance narrow field of view 640x480 Uncooled Infrared Sensor
- Dual-function countermine and recce sensor for Class II OAV

Targeting:

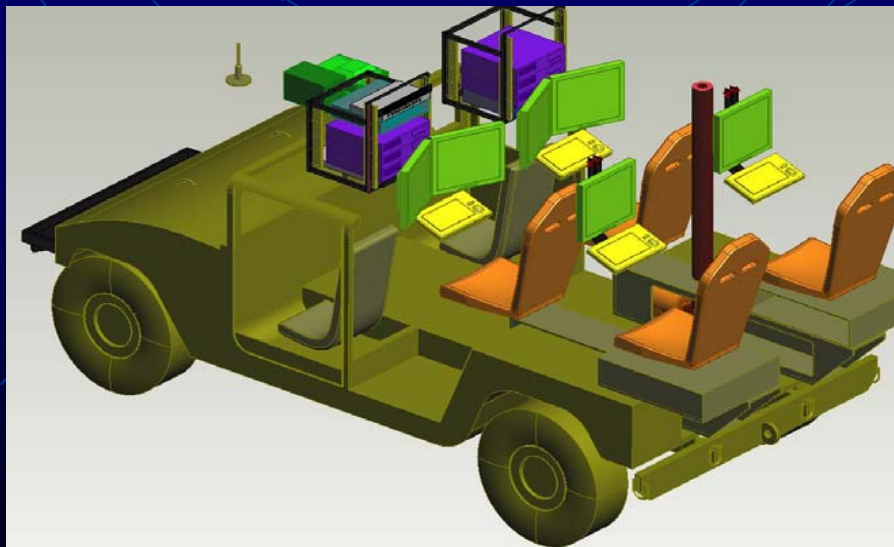
- Man-in-the-loop real-time targeting & image chip generation from Small UAV platform

Networking:

- Demonstration of system-of-systems integration and networking
- Transport of data from sensor layer into tactical internet

Reconnaissance & Surveillance Vehicle

(Surrogate)



Focus: Mobile platform for Mission/Sensor Planning and C2 of sensor systems, gathering & fusion of sensor data, and performing RSTA/Targeting

Approach: Integration of sensor systems into a networked system-of-systems; JTRS comms node for portal into tactical internet; iterative development and integration by sensor system; test/validation via C4ISR OTMTB, and User Demo

Advantages:

- Demonstrates BLOS battlefield SA for the purpose of enhancing the survivability and lethality of the Combat Forces
- Demonstrates single platform to control all sensors
- Demo's human-sensor interface in surrogate platform
- Supports Combat Force concept development and warfighter experiments with the Army.

Key Areas Addressed:

Sensor Command & Control:

- Optimized for C2 of Unattended Ground Sensors, Unmanned Ground Vehicle Sensors and Small-UAVs
- C2 Planning Software to provide battlefield SA and sensor planning & placement assistance
- Operation and control of multiple S-UAVs simultaneously

Networking:

- Networked comm products
- Ground sensor networks.
- Tiered comms architecture prevents data overload by sensors

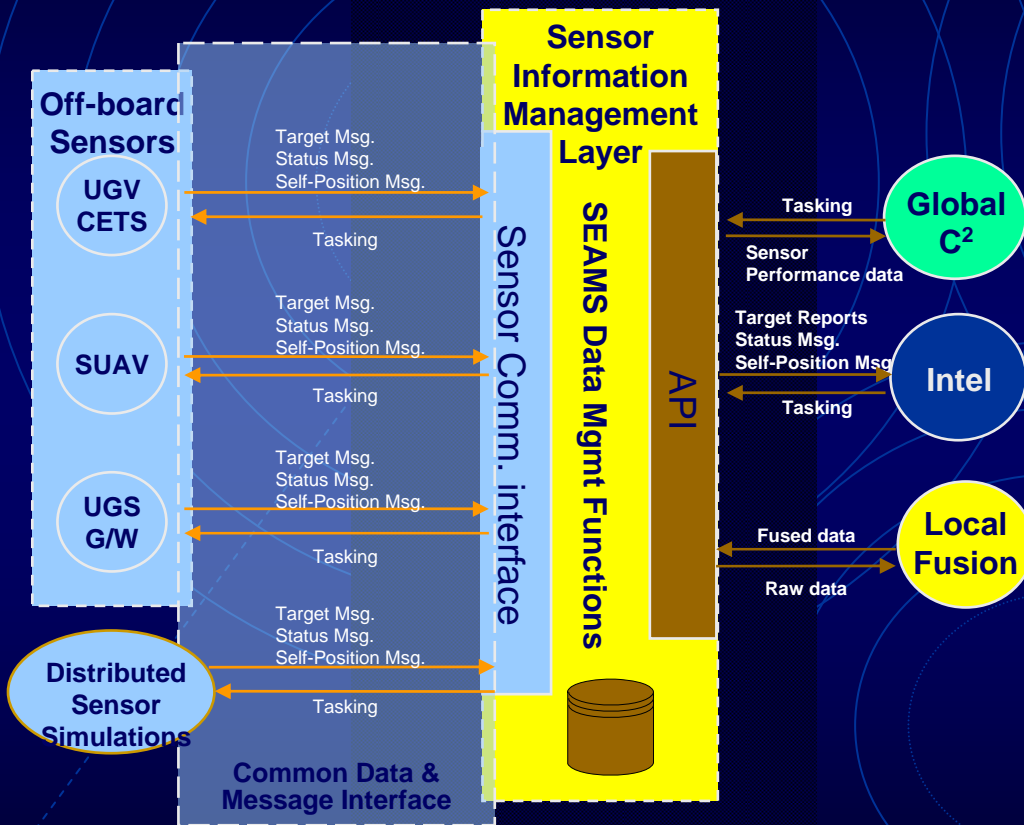
Size/Ergonomics:

- HMMWV-based platform as R&SV surrogate

NSfCF Integration

Vehicle Workstation

Integration Architecture



NSfCF RSV



Software, hardware, and vehicle integration included in RSV development



Raven Small Unmanned Aerial Vehicle

Specifications

Durable Kevlar composite skin with foam core

Sensor payload capacity of 1 pounds

Hand launched / Deep stall Autoland recovery

GPS guided ground based autopilot

Auto gyro-stabilized flight - Pilot commanded speed, climb, and heading control

Dimensions – 54 inch wingspan and 36 inches in length

Aircraft weight – 4.0 pounds max takeoff weight including payload

Portable - Single man, 2 packs totaling 32 pounds including aircraft, batteries and Ground Control Station

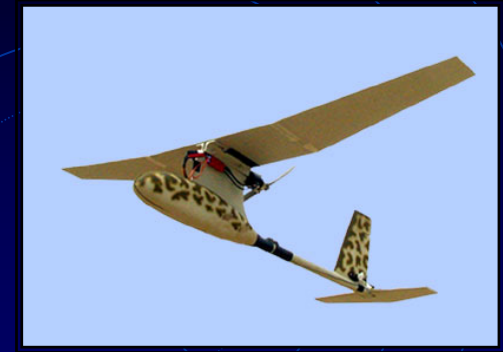
Cruise speed of 30 knots, dash 60 knots, high reliability electric propulsion

9+ KM Range

Maximum duration :

60 minutes - One Lithium Ion rechargeable battery pack

90 minutes - One Lithium non-rechargeable battery pack





Pointer Small Unmanned Aerial Vehicle

Specifications

Durable Kevlar composite skin with foam core

Dimensions – 9' wingspan and 6' in length

Sensor payload capacity of 2 pounds

Hand launched / Deep stall Autoland recovery

Aircraft weight – 9 pounds including payload (maximum 12lbs)

2 man portable - 3 cases (Wings, Fuselage, Ground Control Station)

Commercial and Military GPS guided autopilots available

High reliability electric propulsion

Cruise speed of 22 knots, stall 19 knots, and dash 44 knots

9+ KM maximum range from ground station

Maximum duration

30 minutes - Two NiMh Rechargeable battery packs

80 minutes - Two Lithium non-rechargeable batteries





BUSTER Backpack

Small Unmanned Aerial Vehicle

Specifications

Twin wing carbon fiber composite construction

Dimensions - 3 foot wingspan, 3.25 feet in length

Sensor payload capacity of 2 pounds

Man portable box rail launcher and parachute recovery

10 pound maximum liftoff weight (including payload)

Pivoting wings for storage of airframe and launcher in same box

GPS guided multi-waypoint autopilot with ground station

O.S. FS91 .91 Cubic Inch Engine with electronic ignition conversion

Cruise speed of 40 Knots, stall 30 Knots, dash 60 Knots

10+ KM range of operation from ground station

Maximum duration of 2 hours





Indigo Systems Omega Long Wave Infrared Camera

Specifications

160 Horizontal x 120 Vertical Staring Focal Plane Array

Uncooled microbolometer detector

51 μ m x 51 μ m pixel pitch

7.5 – 13.5 μ m spectral operating band

RS-170a interlaced analog video output

14 bit digital video (IEEE1394 Compatible)

RS-232 digital command and control

Weighs less than 120g, uses less than 1.5W of power

Dimensions - 1.45" H x 1.35" W x 1.9" L

-40 ° C - 55 ° C environmental operating temperatures

F/1.6 & F/1.0 lenses available w/11, 18, and 30mm focal lengths





Nytech Infrared Systems MMB-U4000

Long Wave Infrared Camera

Specifications

320 Horizontal x 240 Vertical Staring Focal Plane Array

Uncooled microbolometer detector

51 μ m x 51 μ m pixel pitch

7.5 – 13.5 μ m spectral operating band

RS-170a interlaced analog video output

RS-232 digital command and control

Integrated shutter for Non Uniformity Correction

Weighs less than 510g, uses less than 2W of power

Dimensions - 2.56" Diameter x 5.06" Length

-36 ° C - 50 ° C environmental operating temperatures

F/1.4 & F/1.2 lenses available with 62mm, or other optional lengths





Raytheon UAV Package Long Wave Infrared Camera

Specifications

640 Horizontal x 480 Vertical Staring Focal Plane Array

Uncooled microbolometer detector

25 μ m x 25 μ m pixel pitch

8 – 12 μ m spectral operating band

RS-170a interlaced analog video output

12 bit digital video, 2x digital zoom available

RS-232 digital command and control

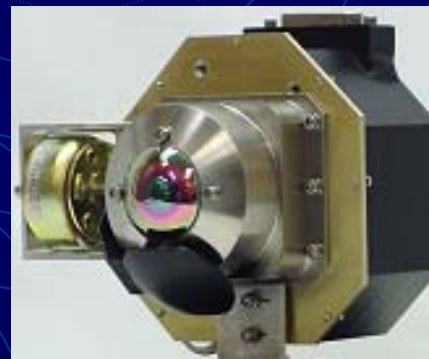
Weighs less than 230g

Dimensions - 3.27" H x 6.62" W x 1.98" L

Uses less than 3W of power

-29 ° C - 49 ° C environmental operating temperatures

F/1.4 Lens available with 22mm focal length





Gantz Light Weight Day TV

Specifications

768 Horizontal x 492 Vertical Color CCD

¼ inch interline transfer, interlaced

Auto tracking white balance

Auto Electronic Shutter 1/60 sec – 1/20,000 sec

RS-170a interlaced analog video output

RS-232 digital command and control

Weighs less than 10 g

Dimensions - 1.5" H x 1.5" W x 1.0" L

Uses less than 1.2W of power

29 ° C to - 10 ° C environmental operating temperatures

Video to 2.0 lx at F/1.2

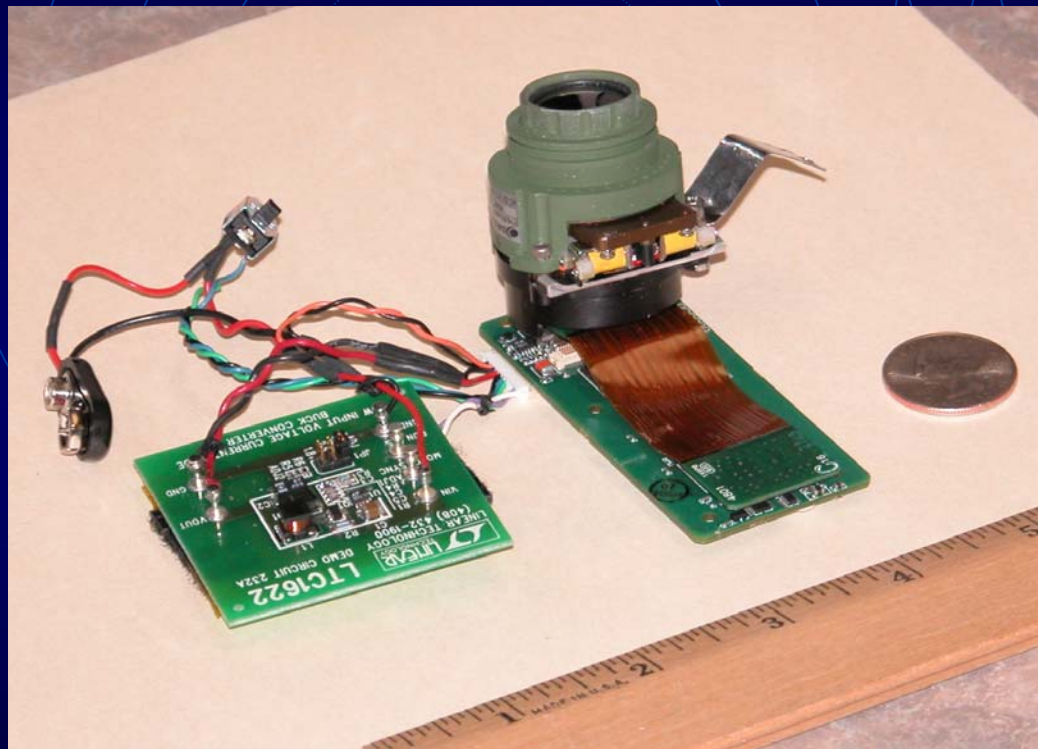
CS mount for lens.





320x240 SUAV Raven

Camera Integration



Separate optical head and control electronics simplified integration of 320x240 imager into Raven nose





Small Backpack UAVs with **Raven UCIR Imager Buster**



320 x 240 Uncooled FLIR



640 x 480 Uncooled FLIR





Key Networked SUAV Development Questions

- Can the RSV operators manage the sensors and workload?
- What is the utility of:
 - Sensor deployment planning at RSV?
 - Level 1 data fusion at the RSV?
 - Uncooled FLIR for SUAV surveillance?
 - Adapting to changes in mission real-time?
 - Can the SUAV fly quickly to locations when needed?

***Satisfying
the Project is
more than
meeting the
technical
criteria***



Emerging User Questions to be Addressed During Demonstrations

- **Do the levels of Sensor performance provide actionable information?**
- **How do terrain and weather affect the limitations of unmanned sensors and the communications?**
- **How do the planning tools work to speed and improve developing an employment concept?**
- **Do the sensors as a package enable offensive/defensive RSTA operations?**
- **What is the impact of message routing on the timeliness of tasks?**
- **What insights can we gather about division of duties within the RSV?**
- **How should sensor control functions be incorporated in the work station?**
- **What are the training implications for unmanned sensors?**



Demo I

System Performance Testing

- **First-look over the past few months:**
 - Evaluate system of systems integration
 - Collect data on sensor performance
 - Conduct activities demonstrating integrated capabilities
- **Integration:**
 - Further development of system integration software tools
 - Further understanding of the capabilities and limitations of networked sensors
- **Data Collection:**
 - Data collected to evaluate performance versus vehicle targets for SUAV, CETS and UGS sensors
- **Demonstrations:**
 - 1) Participated in force on force exercise to determine utility of unmanned sensors – Dismounted Scenario
 - 2) Conducted demonstration of networked sensor capabilities during scripted event - Mounted Scenario



Demo I Demonstrated Capabilities

- **Rapid response to changes in mission providing confirmation of enemy activity in dynamic situations (e.g. UGS Cues).**
- **SUAV used successfully to search large areas in all types of weather: cold, hot, winds to 25 knots, light rain and snow.**
- **Mission duration averaged between 45-60 minutes with 6 hours of flight over 24 hour period.**
- **Able to achieve primary task of scouting lightly forested areas and roads and providing BDA.**



Demo I

Lessons Learned – Control Station

- **Operators able to achieve and maintain good situational awareness with the SUAV.**
- **Current level of information flow makes operator a vital player.**
- **Ability to provide concise packaged information and image products as part of an overall situational perspective needed for quick commander decisions.**
- **Need for automated search patterns to reduce work load**



Demo I

Lessons Learned – Sensors

- Resolution minimum was 240x320 pixels for thermal, 640 x 480 color day TV
- Overall targeting performance seemed best for FOVs about 25° with a down look of 30° and altitudes of 200ft-300ft.
 - Narrower FOVs had better resolution but image flow/aircraft dynamics (roll) affects are much greater.
 - Wider FOVs had poor resolution.
- At altitudes above 600ft-700ft, target detection became difficult due to resolution limitations.
- Greatly desire ability to pan down/follow the target



Demo I

Lessons Learned – Search Technique

- **Search must be as automated as possible**
 - **Automated search patterns for designated target areas highly desirable. Frees operator to view imagery rather than command the aircraft constantly.**
 - **Ability to follow roads and tree lines via map input very useful.**
 - **Local search patterns for cued locations based on time of event needed.**
- **Rapid response to dynamic situations requires multiple SUAVs in the air at the same time.**



Demo I

Lessons Learned – SUAV Image Products

- **Concise data and image produces needed for rapid data analysis by commanders.**
 - ✓ Image chip of 160 x 160 pixels
 - ✓ Target coordinates to 80 meters or less
 - ✓ Date and time stamp
- **Need for even greater image quality for BDA and target identification.**
 - Currently developing a HDTV low resolution (normal frame rate)/high resolution (reduced frame rate) mode to fit within the data link bandwidth.



Demo I

Lessons Learned – SUAV Limitations

- **Communications data link bandwidth is limited.**
- **Line of sight required for data link – low altitude operations/target ID/BDA.**
- **Slow electric powered aircraft in head winds.**
- **Gas engine based SUAV more complex to operate - start up procedure, some tuning depending on temperature.**
- **Need for heavy fuel engine rather than gas for logistics.**



Demo II – Summer 05 System Performance Testing

- **User lead, lab supported testing:**
 - **Operational system evaluation**
 - **Field environment at a US Army field training site.**
 - **Instrumented sensors and aircraft systems,**
 - **Establish final selection of sensors.**
 - **Assess performance against exit criteria.**



Summary

- **The SUAV as part of NSfCF demonstrated how low cost unmanned aerial sensors organic to the local Commander can provide timely Beyond-Line-Of-Sight Situational Awareness and Targeting**
- **The SUAV imagery enabled the commander to significantly increase his area of coverage under dynamic situations providing actionable information.**